

**CERAMIC/METAL COMPOSITE CIRCUIT-BOARD-LEVEL  
TECHNOLOGY FOR  
APPLICATION SPECIFIC ELECTRONIC MODULES (ASEMs)**  
Contract No.: DAAB07-94-C-C009

**TECHNICAL REPORT**  
PERIOD: March 15, 1997 Through June 14, 1997

Sponsored by:

Advanced Research Projects Agency

Electronic Systems Tech. Office

Application Specific Electronics Module Program

ARPA Order No. A840

Issued by U.S. Army CECOM under contract No. DAAB07-94-C-C009

Prepared for: COMMANDER, USACECOM  
PROD & SYS MGMT DIR  
ATTN: AMSEL-LC-ED-SP(J. Page)  
FT. MONMOUTH, NJ 07703

  
\_\_\_\_\_  
Prepared By

June 11, 1997

  
\_\_\_\_\_  
Approved By

June 11, 1997

The views and conclusions contained in this document are those of the authors and should not be interpreted as representing the official policies, either expressed or implied, of the Advanced Research Projects Agency or the U.S. Government.

19970618 050

**Certificate of Technical Data Conformity**

The David Sarnoff Research Center hereby certifies that, to the best of its knowledge and belief, the technical data delivered herewith under Contract No. DAAB07-94-C-C009 is complete, accurate, and complies with all requirements of the contract.

Date: 6/11/87

Certifying Official: Barry J. Thaler

Barry J. Thaler  
Member Technical Staff, Electronic Packaging

## TABLE OF CONTENTS

| <b>SECTION</b> |   | <b>PAGE</b> |
|----------------|---|-------------|
| <b>I.</b>      | <b>WBS Task 2.1: Technology Transfer to Merchant</b>          |             |
|                | <b>Suppliers</b> .....  | 1           |
|                | A.    Task Objective .....                                    | 1           |
|                | B.    Introduction .....                                      | 1           |
|                | C.    Technology Transfer to Dielectric Laboratories Inc..... | 1           |
|                | D.    Plan for Next Quarter .....                             | 2           |
| <b>II.</b>     | <b>WBS Task 2.2: Customize LTCC-M for Specific</b>            |             |
|                | <b>Applications</b> .....                                     | 3           |
|                | A.    Task Objective .....                                    | 3           |
|                | B.    Introduction .....                                      | 3           |
|                | C.    Plan for Next Quarter .....                             | 3           |
| <b>III.</b>    | <b>WBS task 2.3: Fabrication and Testing of Technology</b>    |             |
|                | <b>Demonstration Modules</b> .....                            | 4           |
|                | A.    Task Objective .....                                    | 4           |
|                | B.    Introduction .....                                      | 4           |
|                | C.    Advanced PCMCIA Cards .....                             | 6           |
|                | D.    Power Electronics Building Blocks (PEBB).....           | 7           |
|                | E.    Plan for Next Quarter .....                             | 8           |
| <b>IV.</b>     | <b>Important Findings</b> .....                               | 9           |
| <b>V.</b>      | <b>Significant Developments</b> .....                         | 10          |
| <b>VI.</b>     | <b>Plan for Further Research</b> .....                        | 11          |
|                | Report Documentation Page                                     |             |

## Section I

### WBS Task 2.1: Technology Transfer to Merchant Suppliers

#### A. TASK OBJECTIVE

Transfer the LTCC-M technology to a merchant circuit supplier, Dielectric Laboratories Inc. (DLI). This task will require a steady supply of several custom glasses that were developed during the Phase 1 program. One or more glass producers will be qualified to supply materials to the David Sarnoff Research Center or its designee to produce LTCC-M circuit boards and packages. The Phase 1 technology will be interactively transferred to DLI, who will be qualified by the fabrication of test structures and technology demonstration modules. During this transfer DLI will faithfully reproduce the LTCC-M processes that have been already implemented at Sarnoff.

#### B. INTRODUCTION

In July, 1995 a Technology Transfer program was begun between Sarnoff and Alcoa Electronic Packaging Inc. However, on December 21, 1995 Alcoa announced its intention to exit the ceramic packaging business. In the ensuing months the effort with Alcoa was wound down, and Dielectric Laboratories Inc. was identified as a company qualified to accept an LTCC-M technology transfer and become a merchant supplier of LTCC-M packages and substrates to commercial and military end-users. This ASEM contract was modified on July 16, 1996 to begin the Technology Transfer to Dielectric Laboratories Inc. Based on comments from the Technology Transfer to Alcoa, a number of material improvements have been incorporated into the transfer to DLI. The technology transfer to DLI is now complete, and the final deliverables (20 C-Band Power Amplifier packages) were accepted by Sarnoff.

#### C. TECHNOLOGY TRANSFER TO DIELECTRIC LABORATORIES INC.

The final set of deliverables were delivered by DLI to Sarnoff. These deliverables consisted of :

- 20 C-band Power Amplifiers
- 2 2-sided substrates having 36 metal core feedthroughs and adjoining vias through the LTCC-M ceramic.

The C-band Power Amplifiers were examined by Sarnoff for quality of line definition, cavity definition, ceramic lock-in, plating, and camber. The parts were all judged to be acceptable.

The 2-sided substrates having metal core feedthroughs passed thermal cycle testing at Sarnoff. The parts were subjected to 100 thermal cycles (-40 to +125°C) and then tested for shorts and opens. No shorts or opens were induced by the thermal cycling, and the parts were accepted by Sarnoff.

**D. PLAN FOR NEXT QUARTER**

- No further work is planned in this area

**Section II**  
**WBS Task 2.2: Customize LTCC-M for Specific Applications**

**A. TASK OBJECTIVE**

Extend the LTCC-M technology to meet any requirements of the technology demonstration modules, and any general packaging trends of the electronics industry.

**B. INTRODUCTION**

This task was completed last quarter.

**C. PLAN FOR NEXT QUARTER**

- No further work is planned in this area

### Section III

## WBS Task 2.3: Fabrication and Testing of Technology Demonstration Modules

### A. TASK OBJECTIVE

The objective of this task is to design, fabricate, assemble, and test 4 different technology demonstration modules. These modules are: (1) an optoelectronic transceiver module, (2) a power amplifier package, (3) an advanced PCMCIA card, and (4) a Power Electronic Building Block (PEBB).

### B. INTRODUCTION

The four technology demonstration vehicles planned for this program were chosen because each module had clear military applicability, and also met the requirements of the consumer marketplace. Table III.1 shows the application of each demonstration module to the needs of the US armed forces.

Three of the four Technology Demonstration Vehicles have been fabricated at Sarnoff and shipped to their respective companies for assembly and evaluation. The C-band Power Amplifier was assembled and evaluated with excellent results. Furthermore, this Technology Demonstration Vehicle was also successfully fabricated by Sarnoff's Technology Transfer partner, Dielectric Laboratories Inc. AMP is awaiting delivery of correctly sized ASICs to complete assembly and evaluation of the optoelectronic module. This past quarter the final group of 50 revised design PEBB "lids" were delivered to Harris for assembly and evaluation. Finally work on the Advanced PCMCIA Card (ORBCOMM Modem) continued, with the discovery of a number of "open traces" in the artwork, as well as a large number of artifacts in the original AutoCad files that appear to cause random opens. Many of the "open traces" were fixed by manually revising the screen artwork files, although a few cannot be easily revised, so those traces must be manually "retouched" after screen printing. The artifacts in the AutoCad files cannot be fixed without a completely new layout of the module by Torrey Science. Work continues on developing a AgPd thick film ink system to replace the Ag inks in the metal core feedthroughs.

**Table III.1:**  
**Military Relevance of LTCC-M Technology Demonstration Vehicles**

| Prototype Application   | Supporting Co. | Type                           | Military Relevance   |
|---|----------------|--------------------------------|--|
| Advanced PCMCIA Card (ORBCOMM Modem)                            | Torrey Science | Mixed Signal Module            | <ol style="list-style-type: none"><li>1. Similar electronics needed for global tracking of high value and critical military materials and components (e.g. armaments)</li><li>2. Supports DoD:<ul style="list-style-type: none"><li>• Materials Command</li><li>• Logistics Command</li><li>• Transportation Command</li><li>• "Total Asset Visibility" program</li></ul></li><li>3. Technology applicable to the following:<ul style="list-style-type: none"><li>• NSA (R2) dual function PCMCIA card</li><li>• Trackers</li><li>• Message Terminals</li><li>• CESEL</li><li>• Special Forces replacement of high frequency radio systems (miniaturization)</li><li>• Global extension of communications in Force 21 "Digital Battlefield"</li></ul></li><li>4. Applies to Military Global Mobile Information Systems</li></ol> |
| High Power Motor Controller (Power Electronics Building Blocks) | Harris         | High Power Single Chip Package | <ol style="list-style-type: none"><li>1. Supports US Navy Contract # N-00024-94-C-4088 (an Advanced Tech. Demo. with Naval Sea Systems Command)</li><li>2. Computer controlled Integrated Variable Speed Electric drive for ships (surface and subsurface) and tanks</li><li>3. Computer controlled Electric Actuators for airplanes, ships, and tanks</li><li>4. Auxiliary Power Unit Generators, Solid State Power Controllers for airplanes</li><li>5. Power Inverters and Converters for ships and airplanes</li></ol>   |
| Optoelectronic Transceiver Module                               | AMP            | MCM                            | <ol style="list-style-type: none"><li>1. Supports the construction of low cost broadband networks at military bases and installations.</li><li>2. Such networks support:<ul style="list-style-type: none"><li>• ATM based switching architectures</li><li>• Transfer of large amounts of graphical and multimedia data</li><li>• Digital signals</li><li>• Encrypted signals</li></ul></li><li>3. Supports ARPA contract "Manufacturable Low Cost Single-Mode Bi-directional Links for Fiber in the Loop Optical Networks"</li><li>• Currently LTCC-M is the sole technology for this application</li></ol>  |
| Power Amplifier Packages (microwave)                            | Raytheon       | GaAs single chip package       | <ol style="list-style-type: none"><li>1. Portable government cellular communications systems and wireless LANs</li><li>2. Applies to Military Global Mobile Information Systems</li></ol>  |

## C. ADVANCED PCMCIA CARDS

### Double-sided Substrate Fabrication

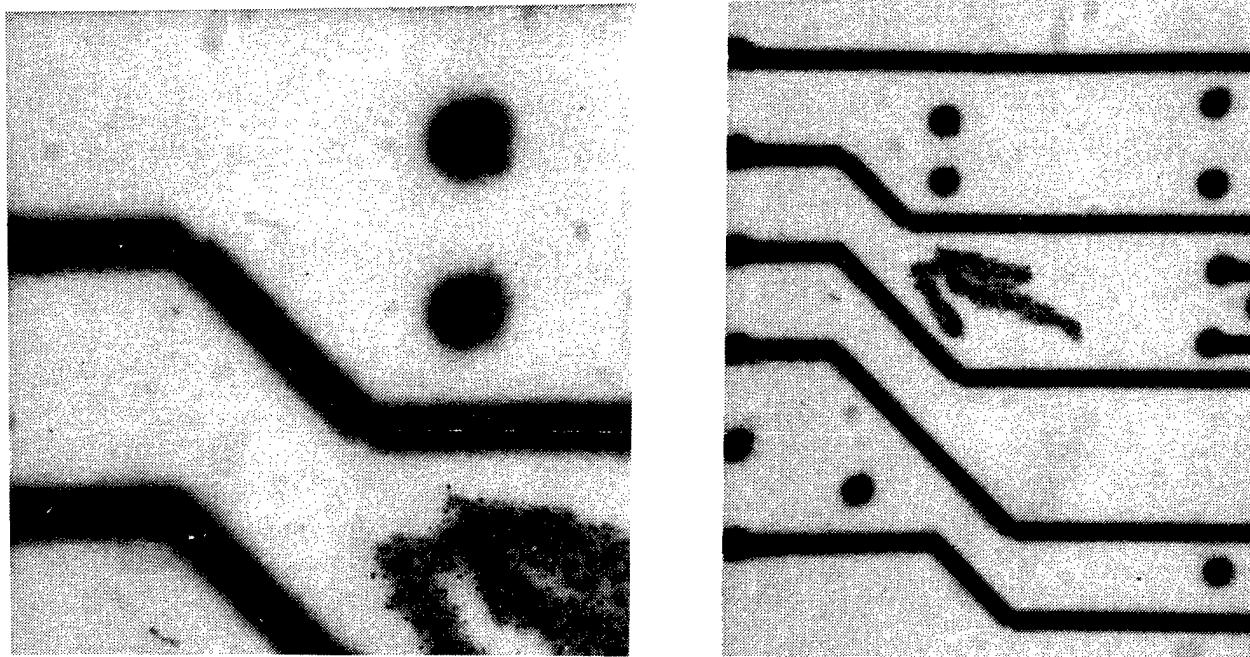
Once tested, Torrey Science will assemble the substrates with surface mounted components. The substrate is 2.13" x 4.5" with a Digital side and an RF side. Although the design calls for 6-layers of ceramic on the digital side and 4-layers on the RF side; 6-layers of tape are being used on both sides to balance the system during cofiring, thereby obtaining flat cofired parts. The board has twenty (20) feedthroughs in the metal core which connect the RF and Digital sides.

The parts are being fabricated using ABT-52 green tape and previously developed ink materials for both the metal core and green tape processing; however, slight modifications were made to the organic vehicles for several of the inks to improve their printing characteristics. The green tape is processed as 5"x5" blanks, which are punched with 8 mil diameter via holes using hard tooling. The via ink and buried conductor inks are Ag-based, and a AgPd based ink is being used as the top metallization, over which Ag pads are printed for wire bonding. LN-1 ink is printed around the perimeter of each top layer, which serves to prevent the formation of a lip at the ceramic outer edges. After cofiring, the excess metal core at the periphery of the double-sided boards is removed by saw cutting, followed by cleaning, surface polishing and electroless plating.

The measures described in the last quarterly Technical Report (3/14/97), have eliminated the shorts to the power and ground planes. This past quarter work concentrated on eliminating the shorts in the metal core feedthrough insulation. It is thought that these shorts may be a result of Ag migration through the glass-ceramic insulators. To mitigate this problem a AgPd(30 wt.%) feedthrough metallization was developed. It has been discovered that reliable feedthroughs still require Ag capture pads on the bottom-side of the green tape layer that will contact the metal core feedthroughs. To minimize the possibility of silver migration, the pad size has been reduced to a 16 mil diameter cover dot. Test structures are presently being built with the AgPd feedthrough metallization to verify the integrity of 2-sided substrates having 12 layers of green tape and feedthroughs in the metal core.

This past quarter, five opens were discovered in the screen artwork used for printing conductor traces. Three of the opens were attributed to violation of the setback rules used for designing the ground plane on the RF side of this module. These three points were manually fixed in the AutoCad layout of this layer. Two additional opens were discovered in the second (from the top) layer on the digital side. These errors are thought to be due to the extensive amount of manual touch-up required by the incoming AutoCad files supplied by Torrey Science.

The AutoCad files supplied by Torrey Science also contain large number of conductor trace constrictions similar to the one shown in Figure III.1. In some cases the constriction reduced the line width to less than one half of its intended width. It is suspected that some of these constrictions crack during the firing process, leading to a few random opens. Newer thick film conductor inks have been formulated to minimize this problem, but all substrates have shown at least two opens attributed to this failure mechanism.



**Figure III.1:** Conductor trace constrictions due to artifacts in the original AutoCad files supplied for artwork generation.

## D. POWER ELECTRONIC BUILDING BLOCKS (PEBB)

### Background

The objective of this task is to design, fabricate, assemble and test a low cost, PEBB "lid" in support of the US Navy PEBB program, and to meet the packaging needs of high current semiconductor devices. PEBB "lids" are high power device substrates that connect the power device to its control signals on a printed wiring board, and also are part of the thermal management system that draws the heat away from the device (and the printed wiring board). This package will eliminate the need for traditional wirebonding for contact formation with external electrodes. This is also a significant improvement over the currently available plastic based power modules that have high parasitic inductance and resistance losses associated with wirebonding. In addition, reliability concerns regarding fatigue of bond wires and fracture of brittle semiconductor die under the stresses of the wirebonding process are also eliminated. The total device size is also reduced. The "lid" package will be designed, assembled and tested by Harris Power R & D and fabricated by Sarnoff.

Sarnoff supplied Harris with a more than 200 PEBB "lids". During assembly of these modules by Harris, it was discovered that the adhesion and solderability of the AgPd was insufficient. The design was revised to eliminate the cofired top conductor, and to have the top conductor layer plated and etched, prior to package singulation.

### **Fabrication Status**

About 100 revised design LTCC-M substrates were fabricated by Sarnoff and shipped to Harris in January. These boards were subsequently sent to Titanium Finishing for plating and returned to Harris for spray etching. However, a change in the standard surface preparation procedure at Titanium Finishing compromised the plated conductor adhesion of this batch of substrates. This group of substrates could only be used for the electrical evaluation of the PEBB "lids". A second group of about 50 revised design substrates were subsequently fabricated by Sarnoff. These substrates have been plated by Titanium Finishing, etched by Harris, singulated at Sarnoff and delivered to Harris for assembly. A thermal evaluation will be performed by Harris Power R & D to complete this Technology Demonstration Vehicle.

### **D. PLAN FOR NEXT QUARTER**

#### **Optoelectronic Transceiver Module**

- All packages delivered to AMP for assembly and evaluation

#### **Power Amplifier Package**

- Technical Demonstration Module is complete

#### **Advanced PCMCIA Cards**

- Eliminate the shorts to the metal core (and revise artwork as required)
- Complete substrate fabrication
- Complete assembly and test of module by Torrey Science

#### **Power Electronic Building Blocks**

- Complete module assembly by Harris
- Complete thermal evaluation by Harris

## Section IV Important Findings

### A. TECHNOLOGY TRANSFER TO DIELECTRIC LABORATORIES INC.

- Technology transfer to DLI was successfully completed this past quarter
- DLI delivered 20 C-band power amplifier packages to Sarnoff
- The double-sided parts test structures that were delivered by DLI to Sarnoff last quarter, passed thermal cycle testing (100 cycles from -40°C to + 125°C) without any degradation.

### B. CUSTOMIZE LTCC-M FOR SPECIFIC APPLICATIONS

- no additional work performed during the last quarter

### C. FABRICATION AND TESTING OF TECHNOLOGY DEMONSTRATION MODULES

#### Advanced PCMCIA Cards

- Discovered several errors (leading to open nets) in the original screen designs, each one will be corrected in future module fabrication
- Redesigned RF ground plane to eliminate opens caused by violation of the setback design guideline.
- Discovered that some feedthroughs are shorting to the metal core. AgPd conductor inks were developed and are being used to minimize the risk of silver migration through the feedthrough insulation layer.
- Developed additional buried conductor inks that are more tolerant of the conductor constrictions caused by artifacts in the original design files.

#### Power Electronic Building Blocks

- An additional 50 revised design PEBB "lids" delivered to Harris Power R & D for thermal evaluation.
- Electrical evaluation of PEBB "lids" completed, with very good results (upon completion of the thermal evaluation, a report will be written by Harris).

## **Section V Significant Developments**

The LTCC-M technology transfer from Sarnoff to DLI has been successfully completed. DLI has already received an order to fabricate another microwave package. DLI is currently quoting prices for LTCC-M packages and substrates.

## **Section VI** **Plan for Further Research**

### **TECHNOLOGY TRANSFER TO DIELECTRIC LABORATORIES INC.**

- The technology transfer has been completed. No further work is planned in this area

### **CUSTOMIZE LTCC-M FOR SPECIFIC APPLICATIONS**

- No further work is planned in this area

### **FABRICATION AND TESTING OF TECHNOLOGY DEMONSTRATION MODULES**

#### **Optoelectronic Transceiver Module**

- All packages delivered to AMP for assembly and evaluation

#### **Power Amplifier Package**

- Technology Demonstration Module is complete

#### **Advanced PCMCIA Cards**

- Eliminate the shorts to the metal core (and revise artwork as required)
- Complete substrate fabrication
- Complete assembly and test of module by Torrey Science

#### **Power Electronic Building Blocks**

- Complete module assembly by Harris
- Complete thermal evaluation by Harris

# REPORT DOCUMENTATION PAGE

Form Approved  
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of the collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

|  |  |  |   |
|--|--|--|---|
| 1. AGENCY USE ONLY (Leave Blank)   | 2. REPORT DATE   | 3. REPORT TYPE AND DATES COVERED<br>Technical Report for: 3/15/97 to 6/14/97 |   |
| 4. TITLE AND SUBTITLE<br>Ceramic Metal Composite Circuit-Board-Level Technology for Application Specific Electronic Modules (ASEMs)  |  | 8. FUNDING NUMBERS<br>DAAB07-94-C-C009                                       |   |
| 6. AUTHOR(S) Dr. B.J. Thaler   |  | 8. PERFORMING ORGANIZATION REPORT NUMBER                                     |   |
| 7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)<br>Sarnoff Corporation<br>CN 5300<br>Princeton, NJ 08543-5300   |  | 10. SPONSORING/MONITORING AGENCY REPORT NUMBER<br>Data Item<br>DI-MISC-80711 |   |
| 9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)<br>Sponsored by: Advanced Research Project Agency<br>Electronic Systems Tech. Office<br>Issued by: U.S. Army CECOM<br>Ft. Monmouth, NJ 07703   |  | 11. SUPPLEMENTARY NOTES  |   |
| 12a. DISTRIBUTION/AVAILABILITY STATEMENT   |  | 12. DISTRIBUTION CODE  |   |
| 13. ABSTRACT (Maximum 200 words)<br><br>The quarterly progress for the Ceramic/Metal Composite Circuit-Board-Level Technology for Application Specific Electronic Modules is described in this report. Data is reported for the following tasks: Technology Transfer to Merchant Suppliers, and Fabrication and Testing of Technology Demonstration Modules. |  |  |   |
| 14. SUBJECT TERMS  |  | 15. NUMBER OF PAGES<br>12  |   |
|  |  | 16. PRICE CODE   |   |
| 17. SECURITY CLASSIFICATION OF REPORT<br>Unclassified  | 18. SECURITY CLASSIFICATION OF THIS PAGE<br>Unclassified | 19. SECURITY CLASSIFICATION OF ABSTRACT<br>Unclassified                      | 20. LIMITATION OF ABSTRACT<br>200 words |